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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : H04L 27/34, 1/16

A1

(11) International Publication Number: WO 92/22162

(43) International Publication Date: 10 December 1992 (10.12.92)

(21) International Application Number: PCT/GB92/00988

(22) International Filing Date: 2 June 1992 (02.06.92)

(30) Priority data:

9111856.2	3 June 1991 (03.06.91)	GB
9114556.5	5 July 1991 (05.07.91)	GB

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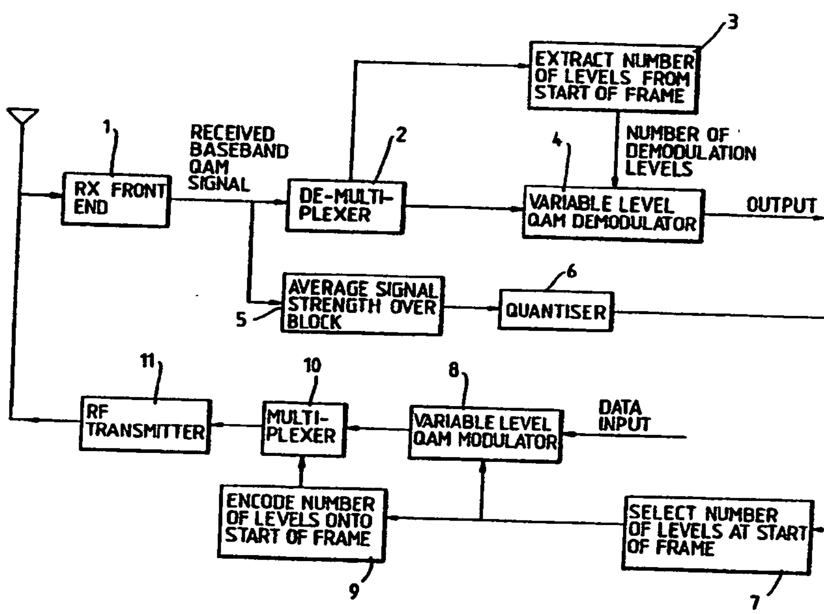
(81) Designated States: AT (European patent), AU, BB, BE (European patent), BF (OAPI patent), BG, BJ (OAPI patent), BR, CA, CF (OAPI patent), CG (OAPI patent), CH (European patent), CI (OAPI patent), CM (OAPI patent), CS, DE (European patent), DK (European patent), ES (European patent), FI, FR (European patent), GA (OAPI patent), GB, GB (European patent), GN (OAPI patent), GR (European patent), HU, IT (European patent), JP, KP, KR, LK, LU (European patent), MC (European patent), MG, ML (OAPI patent), MR (OAPI patent), MW, NL (European patent), NO, PL, RO, RU, SD, SE (European patent), SN (OAPI patent), TD (OAPI patent), TG (OAPI patent), US.

Published
With international search report.

(54) Title: QAM SYSTEM IN WHICH THE CONSTELLATION IS MODIFIED IN ACCORDANCE WITH CHANNEL QUALITY



(57) Abstract

A radio system is so designed as to allow each f a pair of transceivers to assess the quality of the link, and to modify the signal constellation accordingly. Each transceiver monitors the quality of the channel by assessing the strength of the received signal, or the bit error rate, or both. The system is specifically adapted to time division duplex (TDD) transmission over fast fading channel. In each block of data, the first bit is a QPSK (4QAM) signal, which indicates which constellation is to be used.

QAM system in which the constellation is modified in accordance with channel quality.

The present invention relates to a radio system, and in particular, though not exclusively, to a radio system for mobile radio using Quadrature Amplitude Modulation (QAM) as a modulation scheme.

QAM transmissions over Rayleigh fading mobile radio channels are subjected to error bursts due to deep fades, even when the channel signal-to-noise ratio (SNR) is high. This leads to the notion of varying the number of modulation levels according to the integrity of the channel, so that when the transmissions are not subject to fading the number of modulations levels could be increased by increasing the number of QAM constellation points, and when fading occurs the number of constellation points could be reduced to a value which provides an acceptable bit error rate (BER). If the required BER and switch levels are specified accordingly, variable data throughput results. Alternatively, if throughput is kept reasonably constant a variable BER is obtained.

One approach is to have a variable rate system with duplex transmission and some method of informing the transmitter at one end of the radio link of the quality of the link as perceived by the receiver at the other end of the link. The transmitter can then respond by changing the number of QAM levels according to the quality criteria adopted. Successful variable rate transmission requires that the fast fading channel changes slowly compared to a number of symbol periods. If this condition is not met, then the frequent transmission of quality control information will significantly increase the bandwidth requirements of the system.

The present invention seeks to provide a radio system in which transmissions are adapted to transmission conditions.

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According to a fifth aspect the invention provides a radio system wherein the radio communication is bi-directional but instantaneously uni-directional, the data being placed in packets or blocks and the initial symbols in each block being reserved for signalling the number of bits/symbol to be used in the block.

According to a sixth aspect the invention provides a a mobile radio system for operation over radio channels with fast fading wherein the number of modulation levels is varied at a rate commensurate with the fast fading.

According to a seventh aspect the invention provides a radio transceiver comprising:

a radio receiver for receiving radio signals;

means for assessing the received radio signals;

means for selecting a transmission modulation state on the basis of the assessment of the received signals;

a radio transmitter for transmitting signals using a modulation scheme having a plurality of modulation states;

means for adjusting the transmitting state of the radio transmitter to be the selected modulation state; and

signalling means for including in the signals to be transmitted an indication of the selected modulation state.

To reduce the problem of fast fading the data rate could be increased, allowing the transmission of more symbols before the channel changes significantly. The slower the mobile travels, the slower the fading rate and the lower the signalling rate required for adapting to the channel.

Varying the number of QAM levels in response to fading conditions can result in a variable bit rate, which although nearly constant ov r long periods, could instantan ously vary by four times the average rate. Consequently, it is appropriate to consid r strat gies

dictates the number of QAM levels to be used by the MS transmitter. Similarly, the transmission received by the BS enables the number of QAM levels to be used in the subsequent BS transmission to be determined. Both the BS and MS should inform the other of the number of QAM levels used by their transmitters and this information should not be corrupted by the channel, in order for the QAM demodulations to be properly performed. In simulations data was divided into blocks, or packets that occupy a time slot, and the first few symbols in each block are reserved for signalling. The optimum size of the block is related to the mobile speed as the channel should not change significantly over the block duration. Blocks of 100 symbols were used for transmissions at 512kSym/s, a mobile speed of 30mph and a carrier frequency of 1.9GHz. At the start of each block a signal was sent representing the number of levels to be used in the block. This was encoded onto two symbols of a 4-level QAM, i.e., QPSK system, and each of these two symbols was transmitted three times. Majority voting was performed at the receiver in order to establish the number of QAM levels to demodulate in the current block. With larger block sizes, higher integrity codes can be used on the information containing the number of levels without significantly reducing the throughput. Figure 1 shows the TDD framing arrangement for adaptive QAM transmissions using one carrier per channel. If N channels per carrier are used the QAM symbols shown in the Figure are transmitted N times faster, but the time over which the fading channel must remain essentially unchanged is the same, i.e. on the basis that the cells are sufficiently small for flat Rayleigh fading to apply. The QAM constellation changes as the numb r of l vels is varied. Conventional QAM having a square constellation are not used because of the difficulties with carrier recovery in a fading environment. Instead Star QAM having

2-level to 64-level Star QAM are shown in Figure 2. The actual distances between the rings, and the sizes of the rings are not drawn to scale. Each constellation has the same average energy, and the radii of the rings in the 8 and 16-level constellations are in the ratio of three-to-one.

The differential encoding is correctly initiated by using the convention that the point before the first data symbol is sent on the innermost amplitude ring at 0 degrees, and we then calculate our differentially encoded data from this phasor.

The block diagram of a transceiver is shown in Figure 3. After recovering the baseband signal by receiver (RX) front end 1, demultiplexing is performed by de-multiplexer 2 to separate the QPSK and Star QAM signals. QPSK demodulation is performed by QPSK demodulator 3 to obtain the number of QAM levels to be used in the QAM demodulation. This is followed by QAM demodulation by QAM demodulator 4 to yield the recovered data. The average magnitude of the baseband signal level over a block is measured by average monitoring unit 5 to provide an indication of the short-term path loss of the radio channel. If this average is very low the mobile is either in a deep fade or at the edge of the cell. In either case it is more appropriate for it to transmit using relatively few QAM levels. Conversely, if the average is high the channel is relatively good, enabling more QAM levels to be used in its next transmission. The average over a block is computed using an exponential smoothing process which gave more weight to signal level towards the end of the block. This average is quantised by quantiser 6, each quantised output signifying a particular number of QAM levels to be used in the forthcoming transmission.

In the transmitter part of the transceiver of figure 3, the output of quantiser 6 is fed to a level selection

value of the QAM symbols (found at the end of the block) was appropriately scaled by the known receiver noise prior to quantisation. Figure 4 shows an arbitrary segment of the signal applied to the QAM demodulator, and the number of bits/sym selected during this period. The figure was produced from a simulation at 30dB with other parameters as stated previously. Because of the relatively high SNR, much of the time the modem attained its maximum 6 bits/sym.

The second criteria for choosing the switching thresholds achieved a constant average bit rate whilst accepting a variable BER. Here the thresholds derived above were used for the constant BER system and these were multiplied by the same number at the start of each block. This number was derived from the baseband signal averaged over a number of fades. This merely involved adding an extra averaging circuit with the averaging window increased over that used to average over a block in Figure 3, so that it covered many blocks. Therefore as the average signal level rose, for example when moving closer to the base station, the switching thresholds increased accordingly maintaining a near constant average throughput, but variable BER. The average bits/sym could be set to any level within the maximum number of bits/sym by changing the scaling factor associated with the long term average input. Where the average bit rate was the same for both selection criteria, they both gave identical BERs, and can be viewed as equivalent systems. Figure 5 shows switching profiles for this constant throughput scheme over the same section of fading channel as for the previous profile. Again an SNR of 30dB is used. Here there is considerably more level changing in an effort to keep the average to 4 bits/sym. If a lower SNR had been chos n for both graphs then they would appear more similar.

figure 3 in that the receiver part the output of demodulator 4 is provided to a BCH decoder 21. The BCH decoder 21 provides a "no errors" output to decision unit 22, and an "errors detected" output to decision unit 23. Decision units 22, 23 control level selection unit 7 appropriately. Further, in the transmitter part of the transceiver of figure 7 the input data stream passes through channel coder 24 before being supplied to QAM modulator 8.

In order to obtain an estimate of the channel during each received data packet, a BCH(63,57,1) code is overlaid onto the last 57 bits of input data in each block. The input data may already have been channel coded and interleaved using the same system as described in the previous section, the additional coding is overlaid onto whatever data was present. This codec was generally ineffective at correcting errors as it was overwhelmed by the non-interleaved errors in a typical error burst, but it informed the receiver that channel conditions were poor. Such a coding system involved little overhead as it was only applied to the final 57 bits in a block which contained an average of 400 bits. The coded data was applied to the adaptive QAM modulator and the modulated output was up-converted and transmitted. The QAM demodulation was performed using the number of QAM levels extracted from the header, as described in the section on the RSSI switched QAM system. Most of the data was passed to the output where it might be subjected to de-interleaving and channel decoding. However, the final 63 bits of the recovered bit stream were passed through the BCH(6 ,57,1) codec 21 before proceeding to the output. If no errors were detected by this BCH codec then the number of QAM levels used in the next block was doubled, otherwise they were halved. Switching profiles for the same section of channel as used in Figures 4 and 5 are shown in Figure 8. Again a channel SNR of 30dB was

presented. The adaptive QAM modem can be arranged to provide a near constant BER over a wide range of channel SNRs, although the bit rate may vary considerably. This type of performance is suitable for data services that can tolerate some delay. In general, the adaptive modem provides the flexibility to vary both the BER and the bit rate in a prescribed manner to suit a particular application. The adaptive modems have a better performance than the fixed modems both with and without co-channel interference.

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signals assess either or both the received signal strength or bit error rate of those signals.

6. A radio system as claimed in any preceding claim wherein each station has a radio transceiver as defined in any of the preceding claims.

7. A radio transceiver for the transmission of digital signals characterised in that the number of binary digits encoded onto each symbol for transmission is varied according to measured received signal strength, the measured bit error rate (BER) or some combination of these.

8. A radio transceiver characterised in that the received signal strength is averaged over a predetermined time period and the number of bits/symbols to be used in forthcoming transmissions is determined according to this average.

9. A radio transceiver characterised in that errors in received decoded digital signals are identified using an error detection system, and the number of bits/symbol to be used in forthcoming transmissions is based on the number and distribution of the errors detected.

10. A radio system wherein the radio communication is bi-directional but instantaneously uni-directional, the data being placed in packets or blocks and the initial symbols in each block being reserved for signalling the number of bits/symbol to be used in the block.

11. A mobile radio system for operation over radio channels with fast fading wherein the number of modulation levels is varied at a rate comm nsurate with the fast fading.

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Fig.1.

THE FRAMING STRUCTURE USED IN THE VARIABLE LEVEL SCHEME

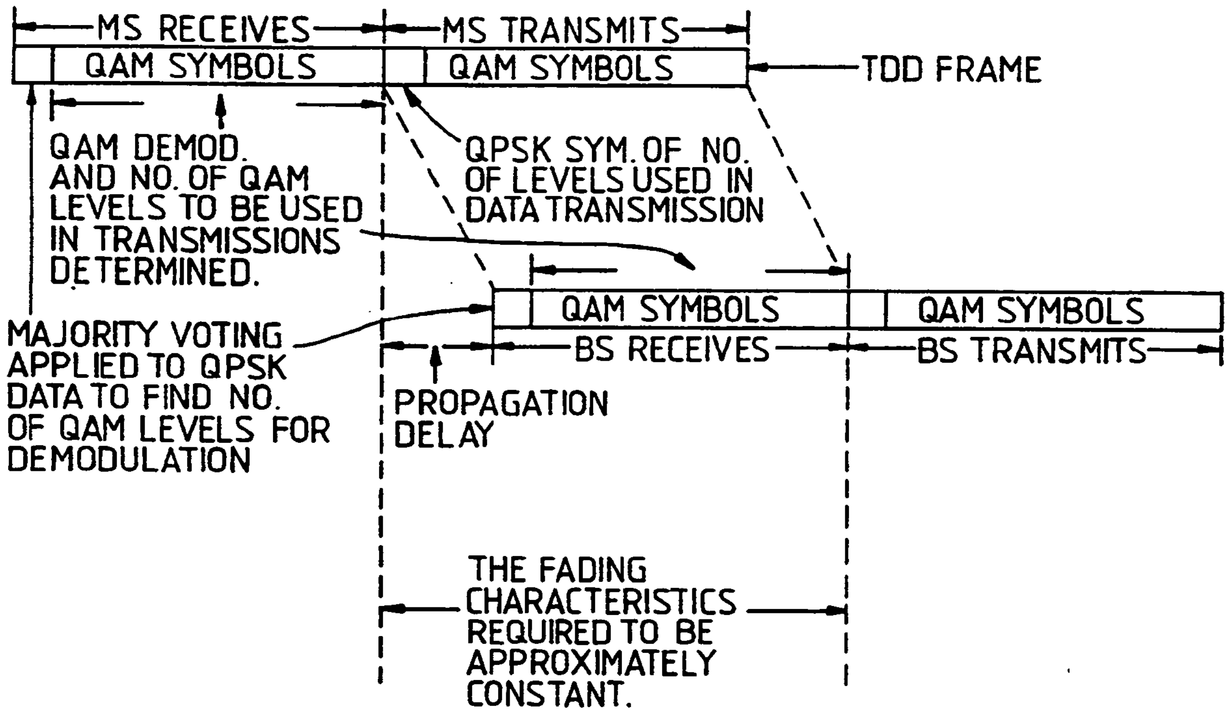
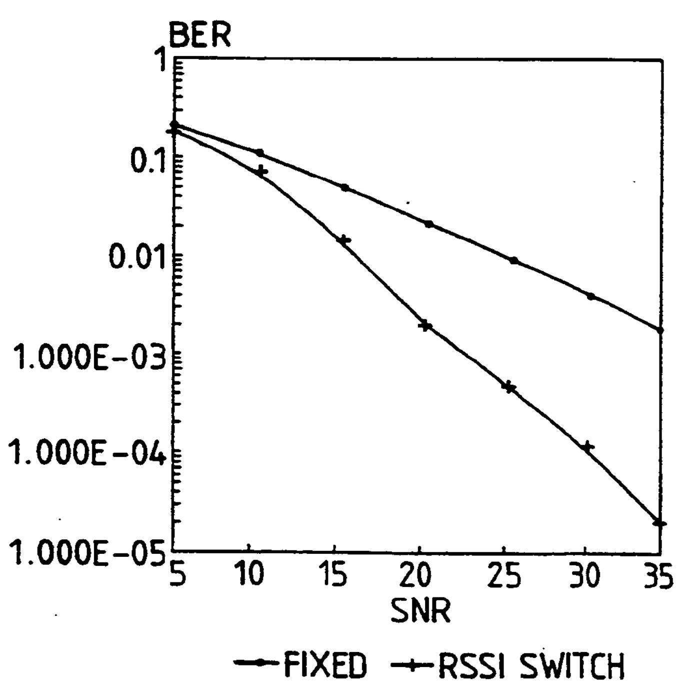


Fig.6.

BER COMPARISON OF VARIABLE AND FIXED SYSTEM



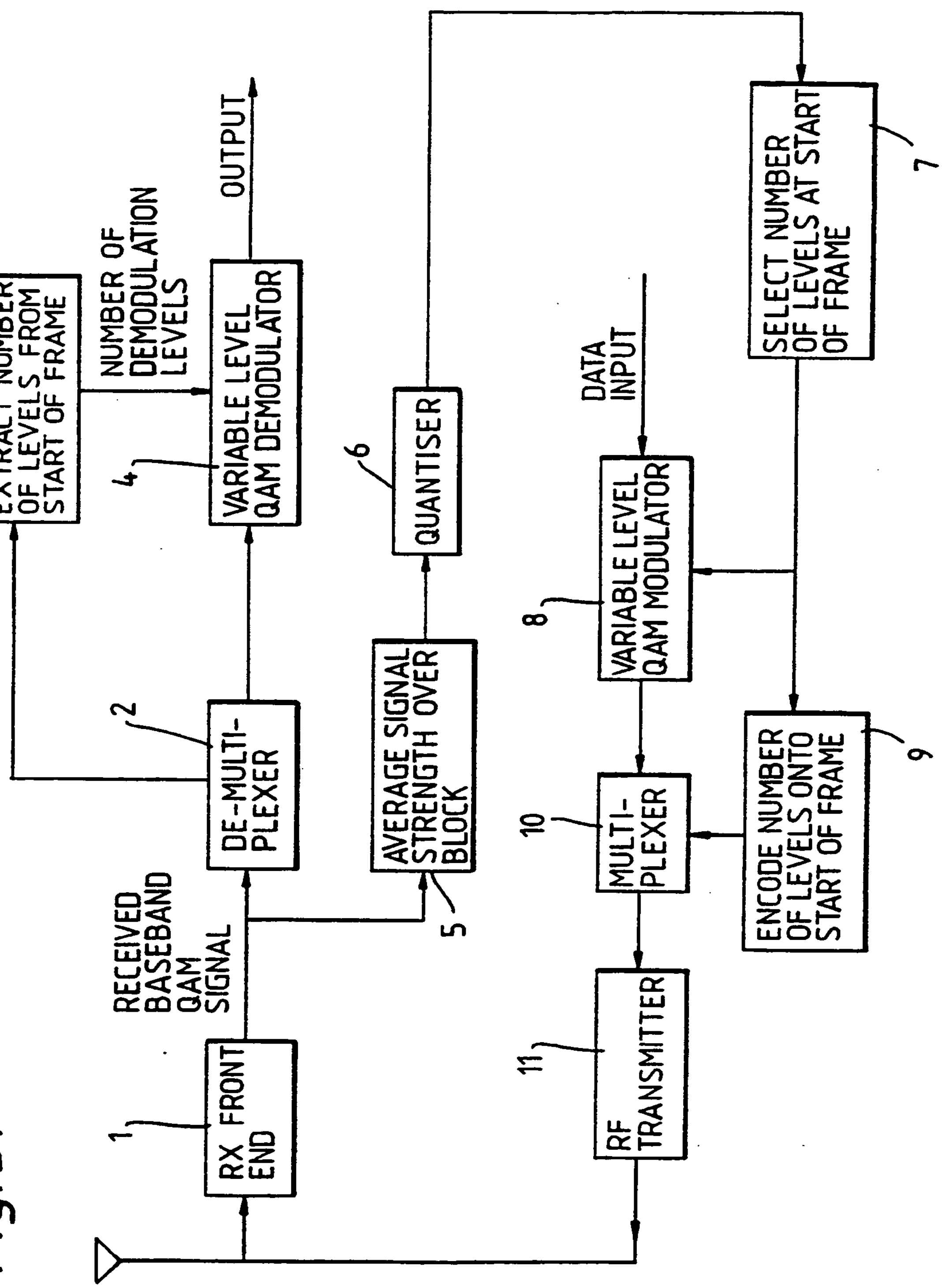


Fig. 3.

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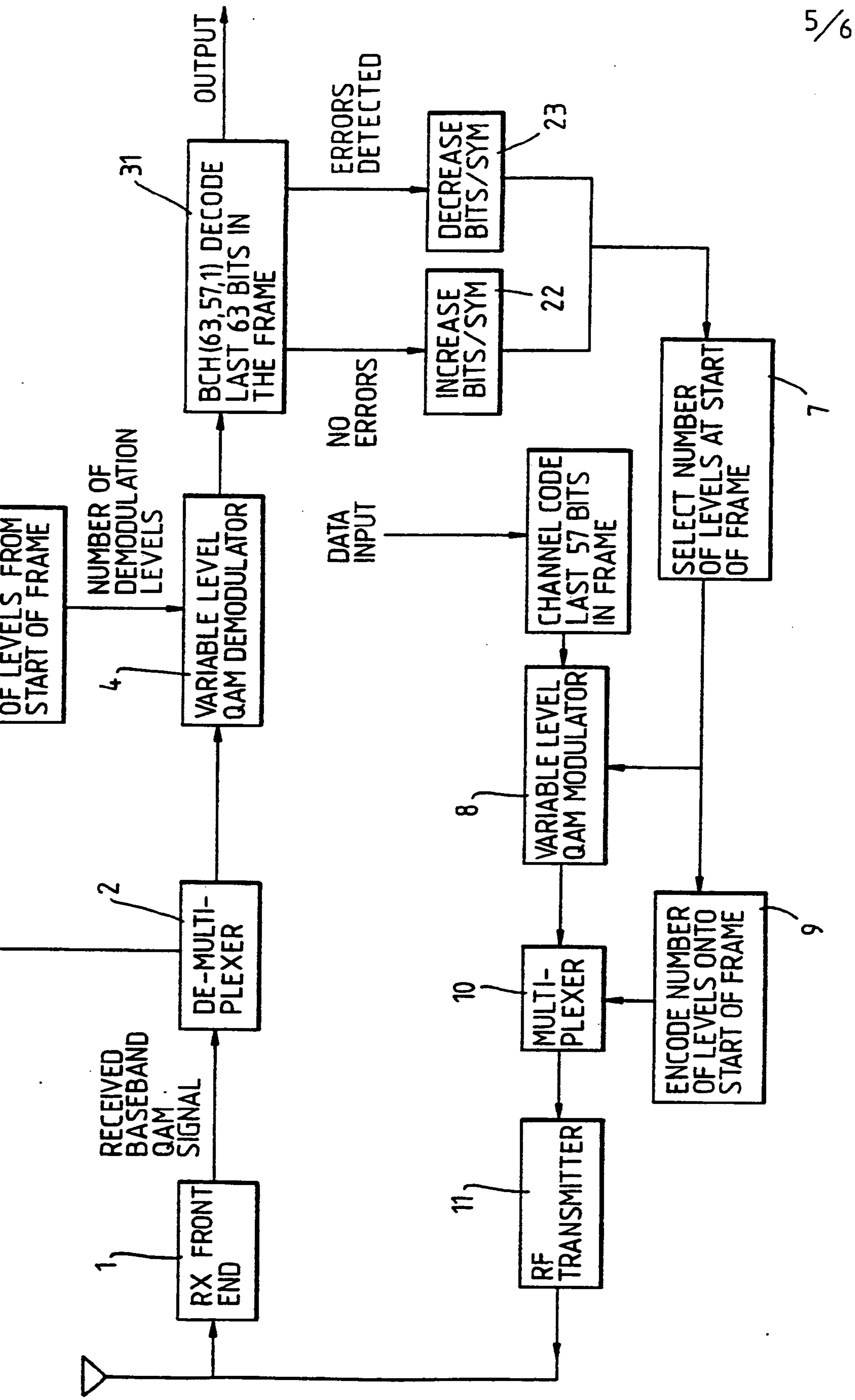

Fig.7.

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SUBSTITUTE SHEET

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 92/00988

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 H04L27/34; H04L1/16

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	H04L

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. D CUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No.[13]
X	US,A,4 495 619 (ACAMPORA) 22.January 1985 see abstract see column 2, line 68 - column 3, line 5 see column 3, line 18 - line 31 see column 6, line 55 - line 62 ---	1-12
X	US,A,4 956 851 (WOLENSKY ET AL.) 11 September 1990 see abstract see column 3, line 9 - line 15 ---	1-12
A	Prodeedings of the 1988 IEEE Military Communications Conference, 23 - 26 October, 1988, San Diego, US; pages 933 - 937; IEEE, New York, US; Jacobsmeyer: / Scheme for Bandwidth - Limited Meteor - Burst Channels see page 934, left column, line 16 - line 21 see page 935, left column, line 1 - line 3 see right column, line 5 - line 8 --- -/--	1-12

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"T" lat[illegible] document published after the international filing date o[illegible] [illegible]ority date and not in conflict with the application but c[illegible] [illegible]o understand the principle or theory underlying the in[illegible]tion

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"&" document member of the [illegible]e patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
24 JULY 1992	14.08.92
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	SCRIVEN P.

1

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ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. GB 9200988 SA 59777

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A-4495619	22-01-85	None	
US-A-4956851	11-09-90	None	

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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